(3)

TECHNICAL REPORT

October 14, 1994

Sponsored by
Defense Advanced Research Projects Agency (DOD)
#BAA 92-20
Issued by Naval Research Laboratory
Contract #N00014-93-C-2026

Applied Science and Technology, Inc.
35 Cabot Road, Woburn, MA 01801
Effective Date: December 31, 1992
Contract Expiration Date: December 31, 1994
Reporting Period: July thru September 1994

Dr. Evelio Sevillano
(617) 933-5560
Title:
"Materials Processing and Manufacturing Technologies for Diamond Substrates Multichip Modules"

DISCLAIMER

"The views and conclusions contained in this document are those of the authors and should not be intepreted as representing the official policies, either express or implied, of the Defense Advanced Research Projects Agency or the U.S. Government."

Distribution Statement: Approved for Public Release: Distribution Unlimited.

Overview

The previous quarter saw attainment of the target 1g/hr diamond deposition at 75kW, as well as full power continuous operation of the AX6600 system. In this quarter we have focused on process chemistry at full power, exploring the operating range of the AX6600 and process chemistry variables. Specific process conditions we have explored include:

* deposition rates from 300 mg/hr to over 900 mg/hr,
* operation from 50 to over 75 kW,
* deposition on areas from 6" diameter to 12" diameter,
* deposition on a variety of substrate materials and techniques for intact release of the diamond at the end of the deposition step,
* deposition of non-uniform films for stress/flatness control.

75kW Reactor & Modelling Studies

The AX6600 design has stabilized, with the latest modifications performing well under continuous full power loads for the last six months. The recent stage redesign (Mar-Apr/94) has proved to be highly successful, allowing continuous high power operation. The 75kW transmitter has also performed quite well, and tube conditioning procedures have been developed for maximizing magnetron lifetime.

The real-time temperature control features of the AX6600 stage were implemented successfully during this quarter, with a control range achieved of about 150 deg-C. The addition of real-time temperature control allows process conditions to be finely adjusted, and substrate temperature fixed through use of pyrometry and a feedback circuit.

We are still optimizing the substrate mounting tooling for the AX6600. The detailed placement of the substrate relative to the plasma, as well as the heat transport through the mounting hardware are critical to achievement of deposition rate and uniformity goals. The design of this tooling must be re-optimized for each substrate size, as well as for major changes in process conditions.

Further reactor modifications are being considered for enhanced performance and/or lower cost, using the GEM 2D code (self-consistent electromagnetic and neutral particle code). Our interests lie in two directions: what can be done to materially improve throughput and/or uniformity of the deposition, and what can be done to reduce reactor cost without deleterious effects on performance. The capability of the GEM code to model details of the EM fields in the reactor cavity, as well as to explore the gradients of both hydrogen and hydrocarbon species has allowed us to study a large variety of reactor modifications in a short time, and will allow us to intelligently choose any further modifications to be tested within this program.

Process Development

We are currently exploring the tradeoffs between growth rate and material quality. The material produced at the highest carbon fractions and power densities (1g/hr material) may not be that most suited for large area MCM use. By varying process conditions (gas content, power, pressure, substrate temperature, substrate position, or substrate material), we can produce diamond of varying quality, as determined by Raman scattering linewidth, thermal conductivity, visual characterization of morphology, flatness & bow, surface roughness (from both morphology and granularity). A great deal of the effort in this quarter has consisted of gathering data to understand these tradeoffs. The conditions studied have primarily been at the higher power levels (over 50 kW), as the lower power levels were thoroughly studied in previous quarters.

As part of the process development, we have been studying the operating envelope of the AX6600 system. Although depositions are normally confined to the 6" to 8" diameter range, we have performed depositions of thermal management material at diameters up to 12", with good results.

Additional effort has been spent in developing a release technique for eliminating the wet-etch of the substrate (needed for growth on silicon). We have made solid progress with development of refractory metal substrate modifications which degrade adhesion. We can now control adhesion from too strong (the film releases partially or not at all) to too weak (the film delaminates during the run from growth stresses), and are continuing to fine tune for intact release of the entire film.

Thermal Conductivity Probe

The assembly of the thermal conductivity probe is complete, and the first measurements have been taken. A series of calibration runs with samples tested at other facilities as well as standard samples (from the NIST "round robin") are underway. We are still refining the diagnostic: performing calibrations and incorporating design changes recently incorporated by the original designer.

Reactor Prototype Related Studies

We are continuing to study high growth rate (HGR) process in our AX6500 (PDS19) reactor, the prototype for the 75kW system, operating at 8kW and 2.45 GHz. The recent efforts have concentrated on uniform depositions for larger area substrates, which scales very well to the AX6600 work. Some preliminary depositions at 4" to 5" diameter in the AX6500 led to the proof-of-principle 12" diameter depositions in the AX6600, for example.

The prototype reactor has also proven useful for small scale studies of unique process conditions. We have recently undertaken a series of runs with non-constant process conditions, in order to form a gradient of a chosen parameter through the thickness of the film. These results will be used to develop "knobs" to be used to control flatness of the film -- i.e. to minimize stress and post-deposition processing.